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# Electromagnetic Bases of the Universality of the Characteristics of Consciousness: Quantitative Support

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**Abstract**

The similar magnitudes of magnetic fields involved with the cerebral operations correlated with consciousness and interstellar and galactic measures may be preconditions for a more universal existence of the conditions that facilitate consciousness phenomena. Quantitative estimates from induced magnetic moments, averaged densities of energies in the universe, electromagnetic interactions, and the temporal solutions derived from these measures suggest that the presence of consciousness-like phenomena within large extracerebral spaces may be more probable than anticipated.

**KEY WORDS:** picoTesla magnetic fields; cerebral fields; extragalactic magnetic fields; Bohr magneton; probabilistic determinism; consciousness

## 1. Introduction: The Electromagnetic Bases of Consciousness

There is converging evidence that consciousness associated with the cerebral volume of the human brain may be identical with or strongly correlated with complex configurations of magnetic fields whose intensities are within the picoTesla ($10^{-12}$ T) range (Anninos et al, 1991; Persinger and Lavallee, 2010). In comparison, magnetic field strengths in the order of $10^{-10}$ T within galaxies and galaxy clusters (Opher et al, 2009) and (unamplified) values with upper limits in the $10^{-13}$ T range (Neronov and Vovk, 2010) for extragalactic fields

have been measured or inferred. They might be considered superimposed upon cerebral values. In this paper, convergence of quantitative estimates and theoretical arguments suggest that the conditions for consciousness may be more universal than anticipated.

There are multiple approaches that suggest the importance of the picoTesla range for the operational magnetic field strength of the cerebral volume that is congruent with the occurrence of consciousness. This approach can assume that either the chemical reactions, neuroelectromagnetic fields, and synaptic spaces within the human cerebral volume create consciousness or the specific neuronal configurations within brain space allow the congruence with electromagnetic conditions that do not originate from neuronal processes, per se, that manifest consciousness. In other words consciousness can be assumed to emerge from the chemical interactions occurring between the approximately $10^{13}$ synapses within the cerebral cortices or as a field that is superimposed within the accompanying vast extracellular and perisynaptic space of this complex volume. The focus here is not to test either hypothesis directly but to discern the quantitative likelihood that the properties of consciousness may exhibit both non-local and local similarities.

Obviously the observation that "similar plus similar equals the same" is not necessarily valid. In addition, scalar identities do not easily reveal the complexity and information density (McFadden, 2002) that must exist as structure within the range of shared magnitudes of magnetic fields. Such spatial-temporal complexity (Tononi and Edelman, 1998) has been argued to be a fundamental characteristic of consciousness (Pribram and Meade, 1999). However a convergence of quantitative solutions could give perspective by which previously disparate levels of discourse might be integrated.

Some quantitative estimates from classical and nonclassical approaches are illustrative. The magnetic field associated with the typical current for an ion channel within the plasma membrane of the neuron is about $10^{-12}$ A. Because the intrinsic energetic characteristics of the ion channel converge with multiple spatial properties that contribute to the resting membrane potential and those of the cerebral volume (Persinger and Lavallee, 2010) this value could be considered fundamental. Assuming an axon is a wire the resulting magnetic field $B=(\mu i)/2\pi r$ where $\mu$ is permeability, $i$ is the current (pA) and r=the distance across the membrane (10 nm) is within the 10 to 100 pT range.

The change in frequency, or a derivative of it, with which consciousness is often associated (Persinger et al, 2010) in non-angular systems from the application of a magnetic field with a strength of $10^{-11}$ T would be, according to

standard Zeeman solutions, within the 1 to 100 Hz range, which involves most of the band-width for the major cerebral correlates of consciousness. In this case, the change in frequency is the product of the strength of the magnetic field and a unit charge ($1.6 \times 10^{-19}$ A s) divided by a constant times the mass of an electron. More specifically, a 40pT field in a non-angular system would produce a change in angular frequency of about 7 Hz. This frequency, and more specifically the theta (4 Hz to 7 Hz) band, is the pivotal frequency that relates the "40Hz" consciousness pattern (Llinas and Pare, 1991) of the cerebral cortical activity with the theta range of the hippocampal formation (Holtz et al, 2010; Lisman and Idiart, 1995; Persinger and Lavallee, 2010), the gateway to memory. From this context it may not be spurious (although unorthodox) that the mass (kg) of an electron divided by a unit charge (A s) multiplied by 7 Hz (1/s) yields a magnetic field strength of $40 \times 10^{-12}$ T.

## 2. Effects of Galactic-level Intensities Upon the Magnetic Moment of Cerebral Matter

In previous papers and experimental research we have been pursuing the concept that minute changes in the intrinsic motions of electrons associated with weakly applied magnetic fields (B) may facilitate understanding of entanglement (Hu and Wu, 2008; Persinger et al, 2008; Persinger and Koren, 2007). The induced magnetic moment corresponding to the change in angular velocity (opposite to B) can be described as:

$$\Delta m = - [e^2 r^2 / 4 m_e] B$$

where "e" is the unit charge, r=the Bohr radius and $m_e$ is the mass of the electron. Classically one applies strong fields. However suppose the intrinsic cerebral magnetic field was applied, i.e., ~10 pT? If this is pursued and the appropriate values are multiplied (*) or divided then :{[$(1.6 \times 10^{-19})$ $A^2 s^2$ * (5.1 x $10^{-11}$) m2]/4 * 9.1 x $10^{-31}$ kg}*$10^{-11}$ T results in $1.8 \times 10^{-40}$ $Am^2$ or J/T. This quantity is a very small value.

However, if one assumes that a second extracerebral field such as that intrinsic within galaxies is superimposed upon a comparable consciousness field of ~10 pT, then the energy associated with this would be $1.8 \times 10^{-40}$J/T * $10^{-11}$ T or $1.8 \times 10^{-51}$ J. The significance of this value becomes apparent because it approaches the rest mass of a photon when $m^2/s^2$ approaches zero, i.e, between $10^{-52}$ kg (Tu et al, 2005) and $10^{-51}$ kg. What occurs at these boundaries is still a matter of speculation although experimental procedures to these implications have begun (Dotta et al, 2011).

What is theoretically more enlightening from the perspective of the considerations in this paper is that even this small amount of energy would have a period or a frequency which can be determined by the dividing Planck's constant by this increment of energy. Hence, $6.624 \times 10^{-34}$ J s/ $1.8 \times 10^{-51}$ J is equal to $3.67 \times 10^{17}$ s. In larger temporal aggregates this is 11.7 billion years, which is within the order of magnitude and variability of the coefficient of the age of the universe. There are several implications of this quantitative association. We have noted in neural systems that narrow bands of energy or ionic concentrations are interconnected and functionally related. For example the "neuroquantal" increment of ~ $10^{-20}$ J (Persinger, 2010), the energy associated with a single action potential, the presumed corporeal bases of consciousness and thinking, ($\Delta v=1.2 \times 10^{-1}$ V * $1.6 \times 10^{-19}$ As) also emerges: 1) at the distance between the charges on the neuronal membrane that create the resting membrane potential, 2) during the intersynaptic transformation of an action potential, 3) during phosphorylation, 4) as the intrinsic energy for the electromagnetic wavelength equivalent of a cell (~10 μm), and, 5) from the energy differential between the solution for the discrepancy between the classical and Compton radius for the electron (Persinger et al, 2008). This congruence between the generalized background of magnetic fields within and between galaxies and the magnetic field coupled to cerebral function would suggest a potential continuity that would not necessary require but also not exclude a neurophysics derived from the philosophies of Spinoza (see Grene, 1973) or Teilhard de Chardin (1955).

One possible model is that the intrinsic magnetic field of the galaxy constitutes the first field that affects the Δm but the application of the second, from consciousness, is required to produce the energy whose temporal solution is the age of the universe. If the latter is valid then changing the intensity of the secondary applied field associated with consciousness would by solution potentially change the age of the universe. That the act of measurement or awareness can affect the measurement is an intrinsic feature of Heisenberg's uncertainty. It may be relevant that if we assume complete certainty of the location of an electron with a classical radius of $2.82 \times 10^{-15}$ m then the uncertainty of momentum is $6.624 \times 10^{-34}$ J s/$2.82 \times 10^{-15}$ m or $2.35 \times 10^{-19}$ kg m/s (Aczel, 2002). At the average bulk velocity of the transcerebral magnetic fields associated with consciousness, ~ 4.5 m/s (Nunez, 1995; Persinger and Lavallee, 2010), the energy would be $10^{-20}$ J, the essential quantal unit of thinking and by extension consciousness.

## 3. The Implication of One Neuron Affecting Cerebral Function

The implications of the recent replications that the firing of only one neuron is sufficient to alter the microstate of the entire cerebral manifold (Li et al, 2009) or determine the 0,1 condition for a rat (Houwelling and Brecht, 2008) to respond or not respond overtly (which requires hundreds of thousands of coordinated neurons) have relevance to any model of consciousness which assumes a distribution over immense numbers of synapses. Given the typical power density of $10^{-13}$ W/m$^2$ of cosmic ray (proton) incidence from potentially distant galaxies upon the earth's surface, this means that the energy within the area of a single cortical column (with a width of about 0.5 mm or .25 x 10-6 m2), which is often statistically determines (controlled) by a single neuron, is about $10^{-20}$ J/s, the energy associated with a single action potential.

We (Koren and Persinger, 2010) have previously estimated that the energy density of the entire universe which can be discerned by the energy equivalence of its mass (~$10^{52}$ kg) is $10^{69}$J. When divided by a likely volume of $10^{79}$ m$^3$, the average value is about $10^{-1}$ J/m$^3$. The energy density within the human brain associated with $10^6$ neurons each firing at 10 Hz with an action potential energy of $10^{-20}$ J is $10^{-13}$ J and when divided by the volume of the human brain (about $10^{-3}$ m$^3$) would be $10^{-10}$ J/m$^3$. Consequently if we assume that conditions with shared vector solutions can potentially interact or at least be resonant, the energy within brain space would be congruent with this average of the whole volume of the universe and would satisfy one of the conditions for a hologram.

## 4. "Free Will" versus Cosmic Statistical Determinism

In light of the recent interest in radio stars and the measurements of $10^{-11}$ Tesla averaged intergalactic and intragalactic magnetic fields, which overlap with the operating intensity of cerebral functions, one obvious question is would there be congruent solutions with the energy of these stars? The energy flux from radio stars is ~$10^{-16}$ [W/m$^2$]/Hz. If we assume the intrinsic brain resonance frequency is 7 Hz (the theta range), then the energy is 6.624 x $10^{-34}$ J s * 7 Hz or 46.37 x $10^{-34}$ J per second (watts). The equivalent within cross-sectional space would be that value divided by $10^{-22}$ W/m$^2$ or effectively an area with a diameter of about 10 μm (7 μm to be more exact) which is the within the range of the width of an average cell soma, including the neuron. As mentioned, the electromagnetic energy equivalence of 9 to 10 μm, is $10^{-20}$ J (Persinger, 2010). The differences in coefficients would be within measurement error and the normal distributions around a central tendency.

In other words the energy equivalence in a 1 Hz band from radio stars would match the energy of a 7 Hz photon applied to cell-level space. Does this

suggest that under specific conditions the change in output superimposed upon or reflected as alterations in "noise", that is cosmic ray incidence, could influence the theta activity range of the human brain and subsequently affect perception, memory, consciousness, and even the perception of "choice" or free will? It may be relevant that Charles Fort (Persinger and Lafreniere, 1977) frequently noted the "coincidence" of mass human events and environmental oddities at the time that "new" stars were first observed or "old" stars "disappeared". These "excess correlations" were dismissed by Fort's contemporaries. However, if only one neuronal quantum can change the behavior of a rat or alter the microstate of the entire cerebral manifold, the question must at least be considered: at what distance can we exclude a potential source?

## 5. Energy Densities of the Human Brain and the Biosphere

The issue of similarities, perhaps manifested as "scale invariance", between macroscopic and cerebral electromagnetic phenomena is at present difficult to answer for galactic magnetic fields because of the limited resolution. However, the marked similarities of electromagnetic patterns within the earth's surface ionosphere shell is not only revealing philosophically but potentially important for understanding human cerebral function. The energy density from $10^{10}$ neurons within the entire cerebral human volume would be about $10^{-7}$ $J/m^3$. There are about 70 to 100 lightning flashes per second world wide, most of which occur within a narrow shell of about 2 km within the biosphere. Assuming a typical 10 Coulomb (C) flow of electrons across a potential difference of $10^8$ V, the energy would be $10^9$ J per flash for a total of $10^{11}$ J/s world wide. The volume of the shell within which the electromagnetic fields associated with lightning patterns occurs is about $10^{18}$ $m^3$ which yields a density of $10^{-7}$ $J/m^3$.

This value is convergent with the average energy density within the human cerebrum associated with thinking and neuronal activity. If about 5 C is distributed within a lightning channel with an average current of 100 A, and is contained within a radius of 1 cm, the resulting cross-sectional current density is about $10^5$ $A/m^2$. The area of the annulus around a 1 μm width axon of average length is about $10^{-14}$ $m^2$. Given the average current of $10^{-9}$A from the approximately $10^3$ ion channels each with 1 pA capacities, the cross-sectional current density would be equivalent to ~$10^5$ $A/m^2$. Such identities of quantitative solutions are not incidental. For example both lightning and the action potential of the axon share the correlates of nitric oxide production, shared salutatory and pulse patterns, similar mass-charge velocity ratios, and interface times between ground-stroke and axon-dendritic back-propagations.

The average magnitude of the magnetic field of the primarily 7 Hz to 40 Hz oscillations within the earth-ionosphere cavity is in the order of 1 pT to 10 pT.

## 6. Conclusions and Implications

Quantitative similarities and calculated solutions for the intensities of magnetic fields associated with cerebral function and those that exist within intra- and extragalactic space suggest that the energetic conditions associated with consciousness and its many variants may be more universal than anticipated. If scale invariance is operative, then the volumes within which the conditions associated with human varieties of consciousness emerge may be substantially larger but would display comparable characteristics. The marked similarities between action potentials and the lightning strikes that generate the earth's own 1 to 10 pT, 7 Hz to 40Hz "manifold" also strongly indicate that if consciousness is simply a property of specific electromagnetic patterns and intensities, a variety of these conditions may exist within extracerebral systems.

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